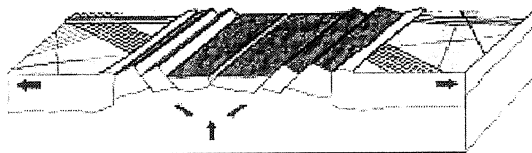


EUROPEAN BANDS FORMED BY STRETCHING THE ICY CRUST: A NUMERICAL PERSPECTIVE.

Ran Qin¹, W. Roger Buck¹, Robert T. Pappalardo², ¹Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY 10964, email: rqin@ldeo.columbia.edu; ²Department of Astrophysical and Planetary Science, University of Colorado at Boulder, CO

High-resolution Galileo images of Europa show linear, curved and wedge-shaped bands crossing the ice surface. These bands are most clearly seen within the region southwest of Europa's anti-Jovian point and make up ~60% of the terrain[1]. It has generally been inferred that bands have formed in response to extension, although Schulson [2] suggests that at least one wedge-shaped band may have formed under compressive stress, analogous to small-scale "wing cracks".



Reconstruction of bands implies that Europa's surface layer has behaved in a brittle or plastic manner, separating and translating atop a low-viscosity subsurface material, with the gap being infilled with relatively dark, mobile material. Two principal models have been proposed for band origin. If Europa's ice shell is very thin (<6 km) and cracks can penetrate through the entire ice shell, then a model of extrusion of water and slush during band opening may be applicable[3][4]. On the other hand, if Europa's ice shell is thicker and ductile subsurface ice plays a significant role in shaping the satellite's geology [5], then bands may have formed from relatively warm ice and would be more analogous to terrestrial mid-ocean ridge rift zones[1][6]

One endmember of Europa's bands commonly exhibit prominent axial troughs, symmetrical spreading from a central axis, large hummocks, tilted fault blocks and bounding ridges (Fig. 1), several kilometers wide and up to 100 meter higher than the surrounding plain. Broadly analogous morphological feature types are also found along terrestrial mid-ocean ridges in the form of axial graben, features of the neovolcanic zone, and abyssal hill normal faults [7]. On the basis of morphology and inferred topography within the bands (such as axial troughs and linear ridges), Prockter et al. [1] proposed that a terrestrial seafloor spreading analog may be appropriate for European bands. Furthermore, these authors speculated that if the bands on Europa are analogous to terrestrial mid-ocean ridges and a similar mode of formation applies to both, then analogous processes may be the cause of variations in morphology and topography among the European bands.

Terrestrial slow spreading ridges generally exhibit prominent axial troughs, large faults and numerous volcanic edifices as new material is slowly formed then rafted away from the central spreading axis. If on Europa, these characteristic bands (Fig. 1) have opened relatively slowly forming cooler, thicker lithosphere close to the axis, allowing significant topography to be supported, this would be analogous to those slow-spreading mid-ocean ridges such as the Mid-Atlantic Ridge.

We are currently adapting a sophisticated numerical model that exists for modeling rifting phenomena on Earth, as developed and first applied to slow-spreading mid-ocean ridge abyssal hill topography by Buck and Poliakov [8], to quantitatively test the hypothesis of European hummocky band formation by stretching its icy crust. The numerical model uses an explicit finite-element method similar to the FLAC (Fast Lagrangian Analysis of Continua) technique of

Cundall [9]. The Lagrangian method allows us to trace the material flow and a remeshing technique is developed to adjust the numerical grid when it's heavily deformed. Advection and diffusion of heat are also included to allow a time varying lithospheric structure. The surface temperature of Europa is around 100 K and increases toward its interior following a proper temperature gradient, probably 5 ~ 40 K/km. The ice of Europa is commonly believed to have elastic-viscoplastic rheology [10][11] which is temperature and strain-rate dependent. In the shallow, cold part of this layer the viscosity is so high that it effectively behaves as a brittle material, approximated with Coulomb elastoplastic rheology, which allows for localization of shear deformation that mimics faults. Warmer regions deform by thermally activated creep. This numerical model will allow us to explore relationships among opening rate, cooling rate, fault initiation, and morphology of rift zones that might be formed by stretching of Europa's icy crust.

Preliminary model runs have been performed with coarse grids to ensure that our algorithms--developed to model faulting in terrestrial rock--will succeed in reproducing tectonic structures in ice. These preliminary runs have successfully produced faults within a thin ice lithosphere with, a transition from brittle to ductile behavior occurring near 0.5 to 3 km (the range constrained observationally [5]), and faults penetrating to near this depth. These results, however, are not yet fully validated. This main goal of our modeling is to produce the surface morphology that will be compared to the morphologies of bands on Europa. Our results will address the first-order question of whether the mid-ocean ridge analog model is an appropriate one to apply to Europa, and if so, will constrain the formation conditions appropriate to formation of bands, notably thermal structure and strain rate.

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